Session 5: Criticality Safety Software and Development

VIM — MONTE CARLO NEUTRON TRANSPORT CODE
(Viewgraphs)

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VIM – PRIMARY FEATURES

- Primarily reactor neutronics → easy reaction rate, balance, and cross-section edits
- Also neutron or photon shielding
- Detailed continuous-energy physics data:
  - probability tables in unresolved resonance range
  - pointwise data in resolved resonance range
  - thermal data processing from modified FLANGE-II
  - 118 nuclides/materials
  - neutron data from ENDF/B-V (or -IV)
  - photon interaction data (from MCPLIB)

- Flexible geometry:
  - combinatorial geometry
  - lattices of hexagonal or rectangular combinatorial cells
  - plate lattice (ZPPR criticals)
  - infinite medium
  - SRS supercell (periodic)

VIM ESTIMATES – ALL CALCULATIONS

- k_{eff}, including optimal combination of pairs of track length, collision, and analog estimates
- Group reaction rates and cross sections by region:
  - macroscopic & isotopic
  - universal tallying helps code speed

- Group scalar fluxes by region
- Total leakage, absorption, production, fission
- χ(E), leakage(E):
  - 1-σ error estimates for all quantities estimated

OPTIONAL ESTIMATES

- Volume-integrated group net currents by region
- Scattering matrices (microscopic)
- Integral reaction rate ratios, e.g., c^8/f^9, f^8/f^9

VIM – NEWER CAPABILITIES

- Group-to-group transfer tallies:
  - inelastic, n,2n, and P_L (or μ-binned) elastic scattering
  - $\bar{\mu}_{gg}$
  - event splitting for variance reduction
  - isotopic cross sections produced
  - error estimates corrected for correlation with scattering rate

- Multigroup calculations, with cross sections from ISOTXS, CASMO output, or ASCII input
- k_{eff} variance assessment:
  - lag-1 generation k_{eff} correlation
  - corrects estimated error

- Elevated temperature data:
  - some actinides up to 2000K
  - some coolants

VIM APPLICATIONS

- ZPPR criticals: k_{eff}, reaction rate distributions, detector fluxes
- EBR-II: core physics, nodal methods benchmarking using interface currents; intermediate sodium activation
- NPR HWR & MHTGR core physics, moderator temperature reactivity coefficients, cross section preparation
- General geometry collision probability method benchmarking
- Reduced Enrichment Research & Training Reactor core physics
- IFR Fuel Cycle Facility criticality hazards assessment
- Intense Pulsed Neutron Source: criticality, power densities from subcritical multiplication, moderator fluxes, counter-diversion analysis
- Space reactor shielding
- TMI-2 ex-core detector response to downcomer water level
- Boron Neutron Capture Therapy flux calculations
- Multigroup cross section generation
- CASMO benchmarking at Studsvik of America

VIM CODING

- FORTRAN 77, except for a few lines (dynamic memory allocation & timing) → portability. In production on Suns & IBM RS6000s. Has run on Cray, CDC, IBM 3084.
- > 3 times faster than MCNP, ~>5 times faster for reactor calculations

- Parallelized for distributed memory Multiple Instruction Multiple Data machines, i.e., RANetwork, IBM SPl:
  - work partitioned by tasks consisting of tens to thousands of histories
  - user control of task size: large tasks reduce message passing; but small tasks provide natural load balancing
  - scalable performance for up 10 processors on RANetwork

- Extensive input checks; lost-particle coordinates and direction shown
- Quality:
  - exhaustive benchmarking vs experiment and other codes
  - under configuration control
  - routine short test problem stream for code modifications not affecting random walks, long benchmark tests for more extensive code changes

- Documentation:
  - user's guide
  - validation bibliography
  - extensive internal comments

VIM BOUNDARY CONDITIONS

- Combinatorial geometry:
  - vacuum
  - white reflection
  - specular reflection
  - Savannah River supercell periodicity

- Repeating lattice geometries:
  - vacuum or specular on various combinations of x, y, z, and hex surfaces
  - periodic on various combinations of x, y, z, and hex surfaces

Sample Detail

	U-235	**U-238**	**Pu-239**	**Ni**
Smooth Data Points	4392	15083	5156	12954
Unresolved Resonance Probability Tables	137	36	94	0
Elastic Angular Distribution Tables	19	29	21	84
Inelastic Angular Distribution Tables	42	121	213	488
Secondary Energy Tables	77	817	4771	643
KBytes	146	291	190	479

VIM Nuclear Data Materials List
Fissionable Nuclides

Isotope	300	560	1000	1500	2000	other
Pu-238	x					
Pu-239	x	x	x			
Pu-240	x	x	x			
Pu-241	x	x	x			
Pu-242	x	x	x			
U-233	x	x	x			
U-234	x	x	x			
U-235	x	x	x	x	x	
U-236	x	x	x			
U-238	x	x	x	x	x	800
Th-232	x	x	x	x	x	
Np-237	x					
Am-241	x					
Am-243	x					
Pa-233	x					
Cm-244	x					
UO_2	thermal x	x	x			

All data ENDF/B-V; 300K and 1000K data available for ENDF/B-IV

VIM Nuclear Data Materials List
Coolants and Moderators

Isotope	Temperatures (K)						
Na-23		300					
He-4		300					
Be-9		300					
K		300					
H_2O	thermal	300	390	560			
D_2O	thermal	300	341	390	438		
C_6H_6	thermal	300					
Be Crystal	thermal	300					
BeO	thermal	300					
graphite	thermal	300	900	1000	1200	1500	2000
CH_2	thermal	300					
ZrH	thermal	300					

All data ENDF/B-V; 300K data available from Version IV

VIM Nuclear Data Materials List
Structure, Absorber, etc.

Cr	Ni	Fe	A-127	Hf-174	Hf-174	Hf-176	Hf-177
Hf-178	Hf-179	HF-180	O-16	C-12	Mo	Mn55	B-10
B-11	Ta-181	Cu	H-1	Pb	Bi-209	Ti	Si
Li-6	Li-7	N-14	Au-197	Mg	Sm-149	Eu-151	Eu-153
He-3	H-2	Ca	V	Co-59	F-19	Cd	Cd-113
In-113	In-115	W-182	W-183	W-184	W-186	Gd-155	Gd-152
Gd-154	Gd-156	Gd-158	Gd-160	Ag-107	Ag-109	Cs-133	Nb-93
Gd-157	Xe-135	Eu-152	Tb-159	Eu-154	Re-185	Re-187	Rh-103
Ta-182	Tc-99	Dy-164	Lu-175	Ba	Ga	Zr-90	Zr-91
Zr-92	Zr-94	Zr-96	Dy-160	Dy-161	Dy-162	Dy-163	Er-167

All at 300K, some also at higher temperatures
All data ENDF/B-V; ENDF/B-IV also available

k_{eff} Comparisons: U Metal Criticals

Critical	VIM σ		MCNP[1] σ		SCALE[1] σ	
SIMP.1	0.97628	0.00079	0.9779	0.0020	0.98366	0.00283
SIMP.1 (Revised)	0.99569	0.00091				
SIMP.2 (H_2O)	1.00087	0.00106	0.9980	0.0024	1.00410	0.00398
SIMP.3 (graphite)	0.99906	0.00083	1.0013	0.0024	0.99967	0.00275
SIMP.4	0.99553	0.00067	0.9933	0.0018	1.00329	0.00272
SIMP.5 (H_2O)	0.99494	0.00089	0.9933	0.0018	1.01183	0.00383
SIMP.6 (graphite)	0.99467	0.00082	1.0002	0.0025	1.01626	0.00343
SIMP.7	0.99174	0.00065	0.9905	0.0022	0.99761	0.00310
SIMP.8	0.99490	0.00069				
SIMP.9	0.99273	0.00067	0.9964	0.0019	0.99246	0.00306
SIMP.10	0.99507	0.00084	0.9966	0.0019	0.99322	0.00287
SIMP.11	0.99604	0.00080	0.9938	0.0021	1.00236	0.00313
SIMP.12	0.99581	0.00069	0.9953	0.0020	1.00263	0.00288
MIH.20 (poly)	0.99689	0.00090	0.9927	0.0023	1.00221	0.00291
MIH.53 (graphite)	1.00076	0.00065	1.0001	0.0022	1.00663	0.00295
MIH.59 (graphite)	0.99755	0.00084	0.9996	0.0026	1.01693	0.00322
ARRAY.2	0.99698	0.00072	0.9982	0.0020	1.00209	0.00309
A.12 (paraffin)	1.00600	0.00090	1.0085	0.0028	1.01750	0.00351
A.51	0.99246	0.00140	0.9946	0.0020	1.00160	0.00279
ROT.2 (H_2O/concr)	1.00469	0.00098	1.0094	0.0035	1.00995	0.00379

[1] *Validation of MCNP, A Comparison with SCALE*, by C. Crawford and B. M. Palmer, WINCO-1110, October, 1992.

VIM k_{eff} for Various Criticals

Critical	k_{eff} (σ)	(k_{eff} - 1)/σ
Jezebel	1.0008 (0.0014)	0
Flattop-EU	1.0072 (0.0061)	1
Flattop-Pu	1.0040 (0.0040)	1
Godiva	0.9972 (0.0007)	4
Jemima(12)	0.9969 (0.0051)	0
Jemima(37)	0.9944 (0.0037)	1
Jemima(53)	0.9943 (0.0025)	2
LTR-II-A	1.0008 (0.0020)	0
IPNS-01	1.0028 (0.0024)	1
IPNS-02	1.0018 (0.0020)	0
IPNS-03	1.0030 (0.0038)	0
ORR	1.0043 (0.0024)	1

RETALLY

- VIM tally postprocessor
- Allows for retrospective tally statistical processing:
  - energy group collapse
  - sum (or average) over unions of regions
  - skip early batches
- Invokes VIM statistical edit package which produces regular VIM edits
- Input produced by VIM, requiring minimal modification

KEFCODE

- VIM k_{eff} postprocessor
- Allows for retrospective k_{eff} statistical processing:
  - skipping early batches
  - aggregate sequential batches
  - skip later batches

XSEDIT

- VIM material file editing program
- ASCII-to-binary
- Binary-to-ASCII
- Binary or ASCII to formatted print
- DISSPLA plot of pointwise data

FILEONE AND BANDIT

- Library collection and preparation for a VIM problem library
- Energy bands (supergroups) for memory conservation
- Up to 40 isotopes in a library

PICTURE

- Line printer zone or composition layouts
- Planar snapshots

SABRINA

- Color renderings of 3-D geometries
- Cuts allow viewing internals of geometry

LOCAL PLOTTING CODE

- Limited to a few body types which define reactor lattices

KENO DEVELOPMENTS

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The series of KENO multigroup, criticality-safety transport codes has been used continuously for over 25 years. During this time KENO has progressed from its original form as a small, highly specific code to the general-purpose criticality code embodied in the latest version, KENO-V.a. Development and maintenance of KENO-V.a is an ongoing effort. Additionally, KENO-V.a is an integral part of the SCALE package, which is also being continually updated and improved. The modifications and developments over the past year relating to the following areas are addressed in this presentation: (1) modifications to KENO-V.a, (2) development of KENO-VI, (3) modifications to the CSAS4 sequence of the SCALE package, and (4) future work on KENO-related programs.

No significant development work has been done on KENO-V.a. The majority of effort here has been devoted to maintenance. A shortcoming involving the use of holes has been remedied. Previously, tangent or touching holes could produce incorrect results. This shortcoming has been removed by reworking the hole-crossing algorithm in subroutines TRACK and CROS. Updated versions of these subroutines will be included in SCALE 4.3 when it is released.

A new version of KENO, called KENO-VI, has been developed and should be ready for release through the Radiation Shielding Information Center in the fall of this year. KENO-VI has all the abilities of KENO-V.a with a more general geometry package. KENO-VI is capable of representing any system that can be modeled by using sets of quadratic equations. A set of 13 geometry shapes is available in KENO-VI. Other shapes can be constructed using sets of quadratic equations. These shapes can be rotated and/or translated to any orientation and position. In addition to rectangular-pitched arrays, triangular-pitched arrays can now be explicitly modeled. The use of array boundaries enables arrays to completely fill regions whose boundaries do not coincide with those of the array. A SCALE version of KENO-VI will be released with SCALE 4.3.

A new search type is currently being developed in SCALE to allow CSAS4 to do a concentration search on a mixture component. The search iterates through the modules BONAMI-S, NITAWL-II, XSDRNPM-S, KENO-V.a, and MODIFY, updating the cross sections in each pass. Plans are underway to similarly modify the PITCH and DIMENSION searches to update the cross sections at the beginning of each pass.

Development work on the series of KENO codes continues. Work has already begun on developing a continuous-energy version of KENO-V.a. Development of continuous-energy cross sections for use in this version of KENO-V.a has also begun. A state-of-the-art graphics package is to be added to KENO-V.a. Plans are being developed to interface an existing graphics package with KENO-V.a that is capable of creating interactive 2-D slices and rotatable images of a system.

Development and maintenance of the series of KENO criticality safety codes are ongoing tasks. The above-mentioned enhancements will be incorporated into KENO as manpower and funding allow.

COG DEVELOPMENTS

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COG is a Lawrence Livermore National Laboratory (LLNL) Monte Carlo computer code that runs on Hewlett-Packard and SUN workstations. It solves the Boltzmann equation for transporting neutrons and photons. It uses pointwise cross sections from the ENDF/B-V library exactly as evaluators present the data. It solves deep penetration (shielding) and nuclear criticality problems.

COG geometry descriptions use either analytic surfaces up to the fourth order or pseudo-surfaces described by boxes, finite cylinders, and topographic surfaces. The geometry can be verified by perspective sector, or material pictures in black-and-white, or in color.

The computer-aided design software Pro/ENGINEER from Parametric Technology, Inc., is combined with the LLNL code Pro/COG to produce geometry input in the proper format for COG.

Three critical experiments for low-enriched fuel rods in water were calculated with COG and the pointwise cross-section set ENDF/B-V. Some characteristics of these critical experiments are presented in Table 1 below.

Table 1. Characteristics of the Critical Experiments.

TRX-1 & -2 WAPD-TM-931 (1970).	BAW 1484-7 (1979) Experiment XIII.
Al Clad 0.387"POD 0.453"ROD 48"long.	1728 Rods 3x3 Bundles 14x14 Rods/Bundle
1.291 w/o U-235 in U.	Al Clad 0.405"POD 0.475"ROD 60" long.
-TRX-1 0.711" Triangular Pitch 763 rods.	2.46 w/o U-235 in U in UO2.
-TRX-2 0.856" Triangular Pitch 577 rods.	1.6 w/o Boron in Boral Plates between bundles.

Some results of these calculations are presented in Table 2 below. They are compared with results using the KENO-V.a code taken from Ref. 1.

These results compare well with these three experiments, and they are within the range of the KENO-V.a results. Benchmarking work for COG against critical experiments is continuing.

Table 2. Benchmarking Calculation Results.

	WAPD-TM-93 (1970)				BAW 1484-7 (1979)	
	TRX-1		TRX-2		Experiment XIII	
	K_{eff}	1 σ	K_{eff}	1 σ	K_{eff}	1 σ
COG, ENDF/B-V	0.9981	.0036	0.9961	.0028	0.9952	0.0033
KENO-V.a, 27GROUPDF4	0.9831	.0032	0.9873	.0030	0.9793	0.0038
123GROUPGMTH	1.0028	.0032	0.9935	.0031	1.0008	0.0041
218GROUPNDF4	0.9761	.0038	0.981	+.0035	0.9789	0.0045

REFERENCE

1. W. R. Lloyd, "Determination and Application of Bias Values in the Criticality Evaluation of Storage Cask Designs," UCID-21830, Lawrence Livermore National Laboratory, Livermore, California, January, 1990.

RECENT DEVELOPMENTS IN THE LOS ALAMOS RADIATION TRANSPORT CODE SYSTEM

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The Los Alamos Radiation Transport Code System (LARTCS) integrates the DANT (Diffusion Accelerated Neutral Transport) discrete ordinates codes with the MCNP (Monte Carlo N-Particle) code. Both codes have a long history of research, development, and application. Since the solution methods of discrete ordinates and Monte Carlo are complementary in a number of ways, the LARTCS is a flexible and powerful tool for solving criticality and fixed-source problems.

The LARTCS is being developed under the umbrella of a graphical user interface (GUI) for problem setup and analysis. This interface simplifies the input and reduces the opportunities for incorrect user problem specifications. The GUI has been under development for over a year and will allow the simultaneous development of both DANT and MCNP input descriptions. The GUI has been tested and analyzed by about a dozen Group X-6 staff. The present version of the GUI is named JUSTINE and will allow the user to set up, view, rotate, and zoom in on geometries in both 3-D solid and two 2-D cut-plane views simultaneously. The software will be portable and will not need any special expensive graphics hardware. Group X-6 anticipates a prototype GUI will be available for customer testing in November 1994.

There has been progress in the DANT system for criticality applications. TWODANT/GQ (for generalized quadrilateral) is available in X-Y or R-Z geometries. This new capability makes it possible to represent nearly any 2-D geometry because the mesh cells can have arbitrary quadrilateral shapes.

The TWODANT and THREEDANT code modules can be linked to a mesh-generation code called FRAC-IN-THE-BOX. FRAC accepts nested region body input and applies a user-specified mesh to the geometry. An interface file is produced which is then read by either TWODANT or THREEDANT. Hence, X-Y or X-Y-Z orthogonal mesh models of almost any combination of nested bodies can be generated. Cells with more than one material are homogenized, but the cell material masses are preserved.

A new iteration scheme that saves considerable computer time for criticality safety problems has been implemented into the DANT system. The normally tight convergence for all the pointwise fluxes can be relaxed for criticality applications. Criticality results for k_{eff} and the fission distribution can now be obtained 20 to 50% faster with no loss in numerical accuracy in the k_{eff} result. There are also new mass and neutron production edits, as well as new print and cross-section file name options.

A DANT System Criticality Tutorial was held at the 1993 San Francisco ANS meeting. About 60 people attended the day-long session on the DANT system, the GUI, and applications. All modules, including THREEDANT, were run on scientific workstations. An early prototype of the GUI was also demonstrated. A total of 28 demo copies of the DANT system (except TWODANT/GQ) were distributed to interested attendees. Discussions about the DANT system are ongoing with interested users concerning code availability and different computer platforms.

MCNP Version 4A was released to RSIC on 10/1/93. The primary focus was on code quality. Any bug found in MCNP can result in a $4 cash award if it really is a bug and has not been found before. The test set of problems has been substantially enhanced to test more combinations of features. The new laws required by ENDF/B-VI physics have been incorporated and tested. The LANL release of the ENDF/B-VI library is expected in the November 1994 time frame. Sixteen-group Hansen-Roach data will also be available at that time.

A new focus put into MCNP4A is on assisting the user in determining if the calculated Monte Carlo results are statistically correct. MCNP now checks criticality problems to determine if all cells with fissionable material have produced at least one fission source point during the calculation. A warning message is produced on the new k_{eff} summary page if all cells have not been sampled. Each of the three MCNP k_{eff} estimators—collision, absorption, and track length—are checked to determine if the batch values appear to be normally distributed at the 99% confidence level. This is the expected result for a converged spatial fission source. If the batch values for all three appear not to be normally distributed, final k_{eff} confidence intervals are not printed in the MCNP output. The first and second active halves of the problem are compared to see if both the mean and estimated standard deviation appear to be the same. If not, a warning is printed. The k_{eff} results are also calculated for a worst-case analysis of each of the three largest k_{eff} s occurring on the next cycle. This is useful for assessing an upper confidence interval based on the k_{eff} s sampled so far.

New MCNP4A tally assessment features involve the relative variance of the variance and the empirical history score probability density function. Both have been incorporated into 4A and are used to analyze the statistical convergence of tally results.

MCNP4A currently runs on many computing platforms, including Cray, VAX, HP, Sun, IBM 6000, DEC, Silicon Graphics, and IBM PCs and clones. MCNP4A can use PVM to distribute one problem to several workstations. An installation package was developed to make it very easy to install and test MCNP. MCNP4A timing studies are presented by Hendricks and Brockoff in the April 1994 issue of *Nuclear Science and Engineering*.

In addition to three 1991/1992 Los Alamos National Laboratory (LANL) MCNP Benchmark Reports, new MCNP criticality documentation is available, or soon will be. The completely rewritten 4A manual contains new or enhanced documentation about MCNP criticality calculations and the new checks. A new criticality primer for MCNP is nearing completion. This work has been done with Chuck Harmon and Bob Busch (University of New Mexico). This primer (see Bob Busch's summary for comments on the primer in Session 6) will be used in upcoming MCNP criticality courses. A new 120-page Los Alamos report by Urbatsch et al. on the three combined k_{eff} estimators used in MCNP is being finished. WINCO has published a four-volume set of MCNP comparisons with SCALE, and INEL has performed an MCNP analysis of the Foehn Experiment.

MCNP training classes have been presented throughout the past year on various topics, including introductory MCNP, variance reduction, and criticality. The next MCNP criticality class in Los Alamos will be August 8-12, 1994. Please contact Judi Briesmeister (jfb@lanl.gov) for more information. Courses have been presented to the AECL in Toronto and Winnipeg (1993) and in Sweden (April 1994). Future courses are scheduled for Tokyo, Japan (1994), and Stuttgart, Germany (1995). On-site courses for the LARTCS can be arranged with LANL on request.

In the future, LANL will have to make a distinction between paying customers and nonpaying users. This is required because of increased budgetary restrictions. Our intent is to make production versions of our codes available from RSIC. Intermediate versions, hotline help, newsletters, classes, new feature developments, and applications will be available only to our customers. LANL is presently formulating an agreement for organizations who wish to join our LARTCS Customer's Group. Relatively small contributions from a large number of organizations will enable LANL to continue to support and develop our codes and data bases, as well as to assist our customers in obtaining the best numerical solutions possible. LARTCS work-in-progress includes requests from the LANL criticality group ESH-6, finishing the GUI, completing a CRADA with Schlumberger-Doll Research, solving various applications problems, presenting training classes, and performing validation calculations.

Anyone interested in information about X-6 should contact the X-6 Group Leader, Bob Little (rcl@lanl.gov). Information on the DANT system can be obtained from Deputy Group Leader Brad Clark (bac@lanl.gov), Kent Parsons (dkp@lanl.gov), Forrest Brinkley (fwb@lanl.gov), and Ray Alcouffe (rea@lanl.gov). MCNP information is available from Monte Carlo Team Leader John Hendricks (mcnp@lanl.gov), Judi Briesmeister (jfb@lanl.gov), Art Forster (raf@lanl.gov), and Gregg McKinney (gwm@lanl.gov). Other persons to contact are the Nuclear and Atomic Data Team Leader Bob Clark (rehc@lanl.gov) and the Graphics Team Leader Stephen Lee (srlee@lanl.gov).

ENERGY-POINTWISE DISCRETE ORDINATES TRANSPORT METHODS

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An accurate determination of the space-dependent flux spectrum throughout an array of fissionable components is one of the most important and basic quantities required in criticality safety analysis. Knowledge of the detailed energy spectrum within the various fissionable and absorber components is needed to determine realistic reaction rates and resonance-shielded multigroup cross sections for subsequent criticality analysis performed with multigroup codes such as KENO. Due to the presence of resonance materials such as uranium and plutonium, the energy spectrum generally exhibits very complex, fine-structure effects within the resolved resonance range that will vary spatially from region to region. Although pointwise Monte Carlo codes such as MCNP can in theory accurately include these effects directly in the transport calculation, multigroup codes such as KENO and all deterministic codes must rely on properly averaged multigroup cross sections to reflect the impact of resonance self-shielding. The great difficulty involved with determining the complicated behavior of the flux spectrum has led to the use of rather simplistic approximations for averaging multigroup cross sections. For instance, equivalence theory and the narrow resonance approximation are inherent in the widely used Bondarenko approach, and the old Nordheim integral method assumes isolated resonances and is limited to only a single absorber component surrounded by moderator. These two methods are currently utilized in the SCALE system to self-shield multigroup cross sections for criticality calculations. Errors introduced into the problem-dependent, self-shielded cross sections by the approximations will propagate into errors in the calculated value of the multiplication factor. Hence, there is strong motivation to develop a more rigorous approach to obtain accurate problem-dependent spectra for multigroup cross section generation.

A new one-dimensional code called "CENTRM" has been developed that computes a detailed, space-dependent flux spectrum in a *pointwise-energy representation* within the resolved resonance range, coupled to a fine-group multigroup calculation above and below the pointwise range. The code uses discrete-ordinates transport theory with an arbitrary angular quadrature order and a Legendre expansion of scattering anisotropy up to P7 for moderator materials and up to P3 for heavy nuclides. The elastic scattering source moments in the pointwise range are evaluated with a new, efficient algorithm called a "sub-moment expansion" developed for s-wave center-of-mass scatter kernels. Pointwise nuclear data is rigorously processed from ENDF/B into a specially formatted CENTRM file, and multigroup data for the non-pointwise range can be obtained from any desired "Working Library" generated by the AMPX code system. For example, the criticality safety libraries in the SCALE system can be used directly in CENTRM.

The CENTRM program provides unprecedented capability to deterministically compute full energy range, space-dependent angular flux spectra in one-dimensional geometries, rigorously accounting for resonance fine-structure and scattering anisotropy effects. The code will become a component in the SCALE system to improve the computation of self-shielded cross sections used in criticality safety calculations, thereby enhancing the accuracy of such codes as KENO.

Several applications to lattices of low-enriched fuel rods are discussed at the workshop presentation. In these examples, an energy mesh of approximately 15,000-20,000 energy points is used in the flux calculation, with an S8 quadrature and P3 scattering. It is shown that the CENTRM-produced multigroup cross sections give critical eigenvalues that agree within about 0.15% of MCNP calculations. Comparisons of CENTRM results to critical benchmark measurements also show good agreement but suggest that the U-238 capture data in ENDF/B-VI predicts more resonance capture than the experiment.

Session 6: Criticality Safety Studies at Universities

CRITICAL EXPERIMENTS WITH MIXED OXIDE FUEL

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Troy, New York

One alternative for the disposal of excess (~100 MT) weapons-grade plutonium (<7 wt% Pu-240) is to burn it as mixed fuel in power reactors (PWRs).[1] The plutonium remaining in discharge fuel would be denatured by increased Pu-240 content (>20 wt% Pu-240) resulting from long residence times. The increased cost from the introduction of plutonium into the fuel cycle would be partially offset by the sale of electricity. Early studies of the use of plutonium in PWRs showed the advisability of a number of modifications in plant design and operation. Several considerations which relate to core physics and safety are (a) higher fissile-to-fertile ratios, (b) lower beta effective, and (c) enhanced use of burnable poisons. Recent studies emphasize the use of distributed Er_2O_3 burnable poison, an important effect of which is to make the temperature coefficient of reactivity more negative.[2] This change occurs because the negative effect of the twin capture resonances in Er-167 at 0.5 eV cancel the positive effect of the 0.3-eV fission-capture resonance in Pu-239.

It is prudent to back up core physics analyses with critical experiment measurements of power shapes, coefficients of reactivity, and critical states. Such analyses[2] for the proposed System 80+ plutonium burner were benchmarked by comparison with results from the Saxton,[3] WREC,[4] and Rensselaer Polytechnic Institute (RPI)[5,6] borated and unborated critical experiments. The Saxton experiments used fuel with relevant fuel composition (6.6 wt% PuO_2 + $U_{nat}O_2$, 90.5 wt% Pu-239 + 8.5 wt% Pu-240) and the RPI experiments used normal enrichment UO_2 fuel with relevant Er_2O_3 concentrations. No critical experiments have yet been conducted for fuel with weapons-grade plutonium and Er_2O_3 together, at various dissolved boron levels, and for specific fuel assemblies such as the ABBCE fuel assembly with its five large water holes. Here we examine the technical considerations involved in carrying out such experiments at the RPI Reactor Critical Facility (RCF). The topics dealt with are the core, the measurements, safety, security, radiological matters, and licensing. It is concluded that the experiments are feasible at RPI.

A representative core could consist of an ABBCE 16x16 fuel assembly surrounded by a 4.81wt% enriched UO_2 driver lattice of SPERT(FI) fuel pins, all in 1/8 core symmetry. All pins would be 6.75wt% Pu in HM + depleted UO_2 at 0.2 wt% tails, 93.5 wt% Pu-239 + 6.5 wt% Pu-240 and normal diameter.[2] Core support, water treatment, control, and instrumentation would be normal.[5] The experiments would be conventional as follows:

a. approach to critical,
b. control rod worths,

c. isothermal temperature coefficient of reactivity,
d. fuel pin worth,
e. void coefficient of reactivity,
f. pin-wise power shape, and
g. absolute power calibration, all at various boric acid levels in the water up to about 300 ppm.

Some of these experiments are carried out solely to satisfy Tech Spec requirements as startup measurements to verifying pre-calculated safety parameters. The control rods are fully withdrawn in the experiments after (b), so all measurements are done on rising periods. The entire campaign of experiments is estimated to involve about 100 periods performed in one calendar month. The total energy production in the campaign would be about 25 W per fuel pin, so the fuel is essentially unchanged. There is negligible fission product inventory at any time, and after a few days the radiation from the pin will decay back to previous levels.

RCF security must be upgraded to Category 1 in accord with 10CFR73.60.[7] Two or more round-the-clock guards are required with adequate training and drills. Required modifications to security hardware include (a) three-strand wire on the top of the security fence, (b) enhanced motion sensors, and (c) bullet-resistant glass on the guard building. The radiological safety requirements at RPI meet or exceed the requirements of 10CFR20. The only upgraded hardware for radiological safety would be better alpha monitoring sensors. The Emergency Procedures should be modified to include ruptured PuO_2 fuel pins. It is anticipated that no information security would be required.

Document submittals would include

a. Amendments to License CX-22 and technical specifications,
b. Amendments to security plan and procedures (10 CFR 73 App C),
c. Modifications to the Safety Analysis Report to note the presence of Pu (no change in the design basis accident, safety limits, or consequences are required),
d. Modified emergency procedures.

In summary, critical experiments at the RCF on weapons-grade plutonium mixed-oxide fuel assemblies appear to be technically and administratively feasible. They would be of appropriate quality and at relatively little cost.[9]

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STUDENT RESEARCH IN CRITICALITY SAFETY AT THE UNIVERSITY OF ARIZONA

D. L. Hetrick
University of Arizona

This is a brief progress report on four student projects at the University of Arizona:

1. simulations of power pulses in aqueous solutions,
2. the effect of assembly shape on the expansion coefficient of reactivity for solutions,
3. some reactivity computations for SHEBA, and
4. computations in support of the French experiment to measure temperature coefficients of dilute plutonium solutions.

The contributing students are Robert Kimpland (now a post-doctoral fellow at Los Alamos National Laboratory), Drew Kornreich (a doctoral student and DOE fellow at the university), and Sung Lee (candidate for a master's degree at the university).

1. Kimpland's dissertation was completed in the summer of 1993. His two-dimensional model for solution excursions shows improvements over previous one-region models. Expansion reactivity coefficients from TWODANT computations may now be used in computations without empirical adjustments. A second improvement is that the computed results for the delayed-neutron tail are closer to experimental data. Thirdly, the pressure-time curves are broader than before (closer to experimental data).

2. Simulation of criticality accidents requires knowledge of shutdown coefficients. The volume expansion contribution to shutdown is a function of assembly shape as well as composition (more important for tall, thin cylinders and less important for squat cylindrical shapes). TWODANT computations have been performed for uranium solutions (various enrichments) and for plutonium solutions, all for various fuel concentrations and aspect ratios. The results may be correlated by simple one-speed diffusion models. The goal is to present these correlations in a form suitable for use in accident predictions that do not require transport theory calculations.

3. We computed critical heights for the Los Alamos Critical Experiments Facility SHEBA assembly, both as it was suspended above its concrete-lined well and when lowered into the well. We used an extremely simple model (a bare cylinder of solution without any structure). We computed a decrease in critical height of 0.74 cm, or alternatively a reactivity increase of 65 cents (a sensitivity of 88 cents/cm). These results are within a factor of two of the preliminary measurements. More refined calculations are needed.

4. Experimental measurements of temperature coefficients in a dilute plutonium solution are planned at Valduc, France. The assembly is a water-reflected cylinder of radius 34 cm and reflector thickness 31 cm. Our computations employed a 69-group model for the spectral part of the temperature coefficient. A typical result (15 g/liter of Pu, 80 percent Pu-239, critical height 76.5 cm) shows expansion feedback of -0.0156 $/°C, spectral feedback +0.0670 $/°C, and net feedback +0.0514 $/°C. The proposed experiment therefore appears to be feasible, but its performance will require care.

CRITICALITY SAFETY RESEARCH AT THE UNIVERSITY OF TENNESSEE-KNOXVILLE

H. L. Dodds
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University of Tennessee, Knoxville

During the past year at the University of Tennessee-Knoxville, graduate students, faculty, and a visiting scientist from Japan have worked on seven different research projects in the area of nuclear criticality safety. These projects are listed below along with the primary beneficiary of each project (i.e., the customer) which is indicated in parentheses:

1. Analysis of a Hypothetical Criticality Accident in a UF_6 Freezer-Sublimer (Portsmouth)
2. Shutdown Mechanisms for a Hypothetical Criticality Accident involving HEU Powder (Y-12)
3. Analysis of a Hypothetical Criticality Accident in a Waste Super-Compactor (Rocky Flats)
4. Criticality Safety Evaluation of the ^{233}U Inventory at ORNL using ENDF/B-V Cross Sections (ORNL)
5. An Update of a Slide Rule for Estimating Criticality Accident Dose Information (NRC/ ORNL)
6. Space-Dependent Kinetics Analysis of a Hypothetical Criticality Accident Iinvolving an Array of Bottles Containing UO_2F_2 (K-25)
7. KENO-V.a Code Development on a Parallel Computer (ORNL)

The first five projects listed above will be described in detail in papers *presented by students* at the national ANS meeting in New Orleans, LA, in June 1994. Preliminary results for project No. 6 showing power versus time are presented in Fig. 1 in order to illustrate results for one of our projects. The transient is for a ramp perturbation of 0.5 $/s in a seven-bottle array of aqueous U (4.98%) O_2F_2. The results indicate that space-time effects are significant beyond $t \cong 70$ s while a simple point kinetics model appears adequate prior to $t \cong 70$ s. These results were obtained with a new code which combines neutronics from the PAD[1] code and thermal-hydraulics from the SKINATH-AR code.[2]

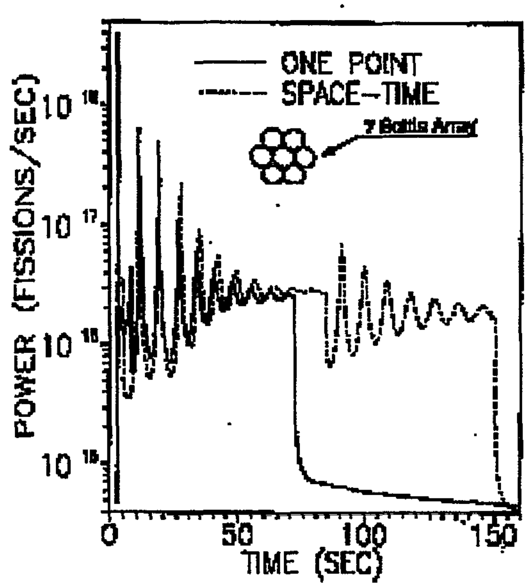

Figure 1. Power vs time (0.5$/s, 7-bottle array.

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NUCLEAR CRITICALITY RESEARCH AT THE UNIVERSITY OF NEW MEXICO

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Albuquerque, New Mexico

INTRODUCTION

Two projects recently undertaken at the University of New Mexico are worthy of note. The university's Chemical and Nuclear Engineering Department has just completed the final draft of a primer for MCNP4A, which it plans to publish soon. The primer was written to help an analyst who has little experience with the MCNP code to perform criticality safety analyses. In addition, the department has carried out a series of approach-to-critical experiments on the SHEBA-II, a UO_2F_2 solution critical assembly at Los Alamos National Laboratory. The results obtained differed slightly from what was predicted by the TWODANT code.

Criticality Calculations with MCNP: A Primer

With the closure of many experimental facilities, the nuclear criticality safety analyst increasingly is required to rely on computer calculations to identify safe limits for the handling and storage of fissile materials. However, in many cases, the analyst has little experience with the specific codes available at his/her facility. This primer will help the analyst understand and use the MCNP Monte Carlo code, Version 4A, for nuclear criticality safety analyses. It assumes that the analyst has a college education in a technical field. There is no assumption the reader is familiar with Monte Carlo codes in general or with MCNP in particular. Appendix A gives an introduction to Monte Carlo techniques. The primer is designed to teach by example, with each example illustrating two or three features of MCNP that are useful in criticality analyses.

Beginning with a "Quickstart" chapter, the primer gives an overview of the basic requirements for MCNP input and allows the reader to run a simple criticality problem with MCNP. This chapter is not designed to explain either the input or the MCNP options in detail; but rather it introduces basic concepts that are further explained in following chapters. Each chapter begins with a list of basic objectives that identify the goal of the chapter and a list of the individual MCNP features that are covered in detail in the unique chapter example problems. It is expected that on completion of the primer the reader will be comfortable using MCNP in criticality calculations and will be capable of handling 80 to 90% of the situations that normally arise in a facility. The primer provides a set of basic input files that can be selectively modified to fit the particular problem at hand.

Although much of the information required to do an analysis is provided in the primer, there is no substitute for understanding a particular problem and the theory of neutron interactions. The

MCNP code is capable only of analyzing the problem as it is specified; it will not necessarily identify inaccurate modeling of the geometry, nor will it know when the wrong material has been specified. Remember that a single calculation of k_{eff} and its associated confidence interval with MCNP or any other code is meaningless without an understanding of the context of the problem, the quality of the solution, and a reasonable idea of what the result should be.

The primer provides a starting point for the criticality analyst using MCNP. Complete descriptions are provided in the MCNP manual. Although the primer is self-contained, it is intended as a companion volume to the MCNP manual.[1] The primer provides specific examples of using MCNP for criticality analyses while the manual provides information on the use of MCNP in all aspects of particle transport calculations. The primer also contains a number of appendices that give the user additional general information on Monte Carlo techniques, the default cross sections available in MCNP, surface descriptions, and other reference data. This information is provided in appendices, so it is hoped that the reader finds the primer useful and easy to read. As with most manuals, users will get the most out of it if they start with Chapter One.

SHEBA-II: APPROACH TO CRITICAL

The approach-to-critical experiment yielded critical heights that were extremely close to SHEBA-II's actual critical height for all three cases examined (Table I). Modeling the system using TWODANT predicted larger values than the system needed to reach a critical state in all three configurations and failed to register the reflective nature of the concrete crypt that is seen in the actual values as SHEBA-II is placed in it. Above ground, the system was critical at 43.72 cm, while below ground it reached critical at 42.40 cm; however, TWODANT runs predicted higher values of 44.2 cm and 44.0 cm, respectively.

The UO_2F_2 fuel solution is worth more when SHEBA-II is in the concrete crypt than when it is above ground (0.43 $/cm versus 0.50 $ and 0.474 $/cm, respectively). This increase in worth is likely due to the reflection of neutrons back into the system from the concrete surrounding it in the pit. The decrease in worth–when the polyethylene lid is placed on top of the pit–of about 0.25 $/cm corresponds to the slightly larger solution height needed for the system to be critical in this configuration and could be the result of fission product buildup or temperature increase.

Table I. Summary of critical heights and solution worths obtained during this analysis of SHEBA-II.

System Configuration	Exp. Estimate	TWODANT	Actual	Solution Worth ($/cm)
Above Ground	43.5±0.2 cm	44.2 (0.17$/cm)	43.72 cm	0.4367
In Crypt Without Lid	42.25±0.15 cm	44.0 (0.35$/cm)	42.46 cm	0.5
In Crypt With Lid	42.5±0.10 cm	44.0 (0.33$/cm)	42.52 cm	0.474

From these results, it is evident that the approach-to-critical procedure is a valuable and quite accurate method for determining the amount of fissile material needed for a system to reach critical. TWODANT is a useful tool in predicting the behavior of a system as fuel material is added but fails to predict the actual critical height accurately. Perhaps adding more of the SHEBA II systems structure, such as its fuel tanks, would improve the accuracy of the TWODANT model, or else three-dimensional transport codes, such as MCNP, might be predictors of the critical height by allowing the evaluation of a more realistic system model.

REFERENCE

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Session 7: Training

TRAINING AT THE Y-12 PLANT

A. Harvey
Oak Ridge Y-12 Plant
Oak Ridge, Tennessee

We regret that a summary of Ms. Harvey's presentation could not be made available for these proceedings.

Editor's note: Ms. Harvey's presentation was to be based on a videotape used to train workers in criticality safety at the Oak Ridge Y-12 Plant. As she explained to the conference, the videotape took as its jumping-off point a 1958 criticality accident at the plant. Although the videotape was not classified, she said, her supervisors nonetheless forbade its showing to the NCTSP Workshop. She said she deeply regretted their decision. Other participants in the conference openly echoed her feelings.

CRITICALITY SAFETY TRAINING

S. K. Woodruff
Los Alamos National Laboratory

Summary

Criticality safety training is an important element of the Plutonium Facility safety program at Los Alamos National Laboratory. Training consists of student self-study handbooks and hands-on performance-based training in a mock-up laboratory containing gloveboxes, trolley conveyor system, and self-monitoring instruments. A 10-minute video tape and lecture is presented to describe how training in this area is conducted.

TRAINING OF NUCLEAR CRITICALITY SAFETY ENGINEERS

R. G. Taylor
Nuclear Criticality Safety Department
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Oak Ridge, Tennessee

Historically, new entrants to the practice of nuclear criticality safety have learned their job primarily by on-the-job training (OJT), often by association with an experienced nuclear criticality safety engineers who probably also learned their jobs by OJT. Typically, the new entrants learned what they needed to know to solve a particular problem and then accumulated experience as more problems were solved. Because more formalism will likely be required in the future, a site-specific analysis of the nuclear criticality safety engineer job was performed and is being used to develop training classes for newer engineers.

The analysis indicated that there are four major components:
1. analysis - assessment of fissile material activities to establish limits and conditions;
2. surveillance - examination of fissile material activities for adherence to established limits and conditions;
3. business practices or administration - integration of the results of analysis with facility operations, e.g., procedures postings, training, how things are supposed to be done; and
4. emergency preparedness - nuclear criticality accident alarm system and emergency responses.

The analysis component was further subdivided into process analysis, accident analysis, and transportation analysis. At this time, the process analysis component is of most interest. By repeatedly asking the question "What does a nuclear criticality safety engineer need to know to do process analysis?," 10 subject-matter areas were identified as candidates for class development, as shown in Fig. 1.

Seven classes have been prepared and delivered to the target audience of newer nuclear criticality safety engineers. These classes address the subject matter areas of basic nuclear criticality concepts, compilations of critical data, and part of basic subcritical limits guides shown in Fig. 1. Response to the training approach has generally been favorable, and the students seem to genuinely appreciate an emphasis on the practical.

The job content analysis has emphasized that nuclear criticality safety, like any other specialized field, has a set of basic information which is not readily recognized by new entrants. The training classes developed from the results of the job content analysis have demonstrated that the specialized information can be successfully delivered to new entrants.

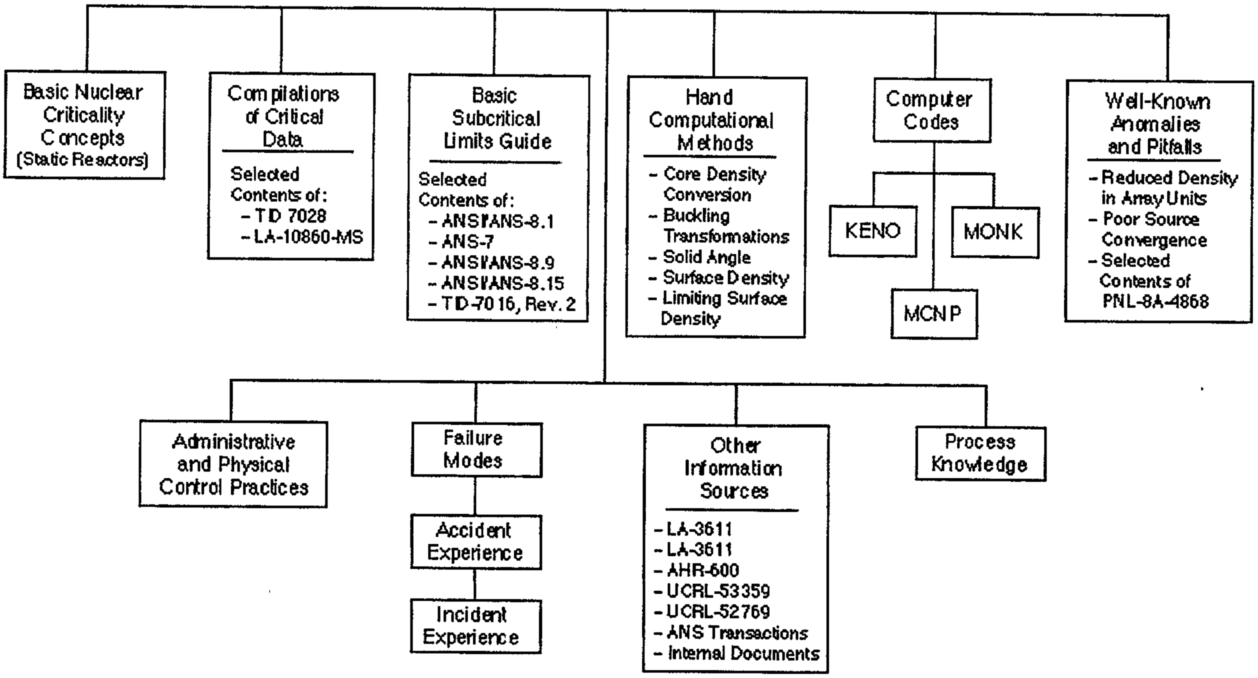

Figure 1. Nuclear Criticality Safety Engineer Process Analysis Job.

NUCLEAR CRITICALITY SAFETY COURSE DESCRIPTIONS

H. L. Dodds

The following two classes are given in the Nuclear Engineering Department at the University of Tennessee-Knoxville.

NE 421: Introduction to Nuclear Criticality Safety

Fundamentals of nuclear criticality safety; criticality accidents; safety standards; overview of experiments, computational methods, and applications.

Text: *Nuclear Criticality Safety - Theory and Practice*, by R. A. Knief, The American Nuclear Society, 1986.

Credit: 3 semester hours

Prerequisites: NE 301, NE 302

NE 543: Selected Topics in Nuclear Criticality Safety

Criticality safety computational and experimental methods for enrichment, fabrication, storage, reprocessing, and transport applications; overview of safety practices and regulatory requirements.

Text: Handout notes provided by instructors plus NE 421 text (by R. A. Knief)

Credit: 3 semester hours

Prerequisites: NE 421

Appendix I

MEETING MINUTES
CRITICAL EXPERIMENT NEEDS IDENTIFICATION WORKGROUP (ENIWIG)
May 9, 1994
1:00 to 2:45 p.m.

Chair: Debbie Rutherford
Vice Chair: Richard Taylor
Secretary: Ernie Elliott

Meeting was convened at 1:05 PM; attendance list is given as Attachment 1.

Ms. Rutherford welcomed the participants and presented an outline of topics to be discussed during the course of the meeting. She requested that if additional needed critical experiments had been identified that they should be listed on the appropriate form and given to her at the meeting or sent in later. The main points of the presentation were as follows (a copy of the presentation is given as Attachment 2).

Summary of Forecast Document

Ms. Rutherford gave a quick overview of the experiments presented in "Forecast of Criticality Experiments and Experimental Programs Needed to Support Nuclear Operation in the United States of America: 1994-1999" (Los Alamos National Laboratory document LA-12638), listing the number of proposed experiments in each of the categories as well as the current prioritization for each. The experiments listed in the document and ranking of experiments within the particular categories were the subject of an extensive meeting in Golden, Colorado, in July 1993, so this particular subject was not readdressed. Questions were raised about the number of experiments that could be performed in a given year. Consensus was that about three experimental series could be performed per year, although this number would vary greatly according to the number of individual critical assemblies that needed to be constructed. Some experimental series may involve only a few (5-10) assemblies, whereas others may require hundreds. Another issue raised concerned the DNFSB Recommendation 93-2. This recommendation addresses not only actual performance of critical experiments as a priority but also maintenance of the capability (personnel, facilities, etc.) to conduct experiments. An additional consideration regarding future capability is conduct of critical experiments for currently unforeseen and specialized situations, with radioisotope production given as an example.

Status of Critical Mass Laboratories

Ms. Rutherford moved on to the status of critical experiment facilities around the country, beginning with the Los Alamos Critical Experiments Facility (LACEF).

LACEF - One training class has been conducted since the beginning of the fiscal year and some experiments are also being performed. LACEF is reported to be operating well, considering the prevalent regulatory environment. SHEBA, Comet, Flattop, and Big Ten have operated recently. No operations with Skua and Godiva are planned, since Kiva 3 is undergoing restoration at the present time. The importation of LEU fuel pins to the Pajarito Lab (LACEF) is being encouraged with potential applications including burn-up credit experiments and LEU fuel-pin array criticals.

Rocky Flats Plant Critical Mass Laboratory - The facility is operable in that the equipment is still in working condition, but it is dead from a regulatory perspective. Shipment of highly enriched uranyl nitrate (HEUNH) solution has lost funding recently and is not being currently pursued. Rocky Flats is switching from Defense Programs to Environmental Management moneys and this has led to uncertainty about disposition of HEUNH. Storage of this material is technically sound for the long term but is out-of-date procedurally.

Other facilities and comments - Beattis and KAPL (unpressurized) critical facilities have been shut down. Rensselaer Polytechnic Institute (RPI) may be available to do some experiments. The Russians and French may be contacted concerning the feasibility of contracting some work. LACEF has been approached by the Navy for some experiments. Part of the Sandia National Laboratories CX machine is also being shipped to LACEF.

DOE Response to DNFSB Recommendation 93-2

Burt Rothleder of DOE provided this information. Mr. Rothleder stated that a Nuclear Criticality Experiments Steering Committee (NCESC) had been formed under Defense Programs. It consists of two subcommittees: (1) Training and (2) Methodology and Experiments (MES). The task MES has undertaken is to extract from LA-12683 a short list of experiments to initially fund and expand the LA-12683 write-up to be more specific. This list is presented as Attachment 3. He also suggested that perhaps analytical work (calculations) could replace the need for some of the experiments proposed in LA-12683. Mr. Rothleder stated that the steering committee is dependent on the experiment needs working group for direction and information. He said that the existence of LA-12683 had given the steering committee essentially a one-year head start in their work. Otherwise, a similar document would *have to* have been produced by DOE. Ms. Rutherford distributed the DOE "short list" of experiments at the beginning of this meeting.

A question was raised about when the decision would be made by DOE concerning experiment funding. Mr. Rothleder responded that the decision should be made by FY 1995. The current source of this funding is unknown, but that the force of safety and economics will eventually lead to funding. Details of experiment selection by DOE (the "short list") will be given during the NCTSP meeting tomorrow (5/10/94). A request was made for more information on the training subcommittee and when training would commence. Mr. Rothleder said that the subcommittee was formed from many components within DOE and that an appeal for funding on a temporary basis had been made. Dick Malenfant added that one training class had been held at LACEF in February 1994. Funds allocated for that particular training course ($50,000) have been spent in conducting the course and associated facility upgrades. He also said that Tom McLaughlin has proposed holding one class per month, depending on the availability of funds.

Reaffirm/Redraft ENIWIG Charter
(The current charter for ENIWIG is listed in Appendix F of LA-12683).

Ms. Rutherford led the members of the working group through the different paragraphs of the charter. Discussion began and continued for quite a while concerning the Purpose and Scope sections of the charter. Comments made by attendees indicated that both sections should be made as generic as possible to include all parties that have interest in experiments that would provide more data for application to criticality safety. The other sections (membership, responsibilities, etc.) required only minor corrections. It was agreed that the Purpose and Scope would be re-drafted in light of comments from the membership and be distributed for comment at the NCTSP meeting on 5/10/94. The newly drafted charter is presented as Attachment 4.

The meeting was adjourned at 2:43 PM.

Respectfully submitted,

Debbie Rutherford — 5/23/94
Debbie Rutherford, Chair — Date

Richard G. Taylor — 5/19/94
Richard Taylor, Vice Chair — Date

Ernie Elliott — 5/18/94
Ernie Elliott, Secretary — Date

ATTACHMENT 1
EXPERIMENTAL NEEDS IDENTIFICATION WORKGROUP ATTENDEE LIST

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Fort Magruder Inn
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ATTACHMENT 2

Agenda - *Experimental Needs Identification Workgroup*

- **Welcome and Introductions**
- **Summary of "Forecast" Document - LA-12683**
- **Brief Status of Critical Mass Laboratories**
- **Status of Critical Experiments**
- **DOE Response to DFNSB 93-2**
- **Reaffirm/Redraft the ENIWIG Charter**
- **Call for New Experiments and Experimental Programs**
- **Next Scheduled Meeting**
- **Conclusions**

Experiments and Experimental Programs Identified by ENWIG That Address DNFSB Recommendations

DNFSB Recommendation	Experiments or Experimental Programs
". . . maintain a good base of information for criticality control, covering the physical situations that will be encountered in handling and storing fissionable material . . ."	104, 106, 202, 203, 302, 303, 305, 306, 402, 502g, 502h, 504, 406, and 701
". . . theoretical understanding of neutron multiplication processes in critical and subcritical systems . . ."	103, 105, 204, 205, 207, 208, 301, 501, 502, 502a, 502d, 502e, 502f, 502i, 503,
". . . to ensure retaining a community of individuals competent in practicing the [criticality] control."	505, 601, 605, 605a, 609, 702, 703, and 704 All experiments and experimental programs, specifically 507 and 508 - training
". . . experiments targeted at the major sources of discrepancy between the theory and the experiments . . ."	101, 102, 304, 606, and 707

Identified and Prioritized Experiments and Experimental Programs

Categories		Number of Priority: Priority 1	Priority 2	Priority 3
Highly-Enriched Uranium	(HEU)	2	5	0
Low-Enriched Uranium	(LEU)	2	5	1
Plutonium	(P)	4	1	0
Plutonium/Uranium Fuel	(PUF)	0	1	2
Transportation/Applications	(T/A)	9	8	0
Baseline Theoretical	(BT)	5	2	4
Criticality Physics	(CP)	1	5	1
	Total (58)	23	27	8

Highest Priority Experiments and Experimental Programs

Category	Experiment	Experimental Program or Experiment Title
HEU	104	Advanced Neutron Source
	106	TOPAZ-II Reactor
LEU	206	SHEBA Reactivity Parameterization
	207	SHEBA Reactivity Void Coefficient
P	301	Plutonium Solution in the Concentration Range from 8 g/L to 17 g/L
	303	Effectiveness of Iron in Plutonium Storage and Transport Arrays
	304	Plutonium with Extremely Thick Beryllium Reflection
	305	Arrays of 3-kg Pu-Metal Cylinders Immersed in Water

cont.

Highest Priority Experiments and Experimental Programs (cont.)

Category	Experiment	Experimental Program or Experiment Title
T/A	501	Assessment for Materials Used to Transport and Store Discrete Items and Weapons Components
	Prog. 502	Waste Processing, Transportation, and Storage
	502c	Validation of WIPP Hydrogen Generation Calculations
	502h	Minimum Critical Mass of Fissile-Polyethylene Mixture
	502i	Criticality Studies that Emphasize Intermediate Energies
	Prog. 503	Validation of Criticality Alarms and Accident Dosimetry
	Prog. 504	Accident Simulation and Validation of Accident Calculations
T/A	Prog. 505	Evaluation of Measurements for Subcritical Systems
	508	Development of a Demonstration Experiment
BT	601	Critical Mass Experiments for Actinides
	606	Establishing the Validity of Neutron-Scattering Kernels
	607	Extending the Standard ANSI/ANS 8.7 to Moderated Arrays
	608	Fission Rate Spectral Index Measurements in Three Assemblies
	609	Validation of of Calculational Methodology in the Intermediate Energy Range
CP	702	Spent Fuel Safety Experiments (SFSX)

ATTACHMENT 3
EXPERIMENT RATING SYSTEM

1Exp = ill-defined subcriticality margin: rating = 8;
2Exp = uncertain protection by well-defined subcriticality margin: rating = 5;
3Exp = discrepant validation of subcriticality margin: rating = 3;
4Exp = criticality safety enhancement through economic gain: rating = 2;
5Exp = enhancement of criticality safety knowledge base: rating = 1;
6Exp = economic gain, independently: rating = 0;
Undecided (U) or Independent of the rating system (I).

The Exp ratings may be multiple, except for those of the 1Exp and 2Exp categories since these categories are mutually exclusive. Since multiple ratings can allow an experiment with a set of lower category ratings (e.g., 3Exp+4Exp+5Exp) to outscore an experiment with a single 5Exp rating if a 1,2,3,4,5 rating system were used, a Fibonacci series will be used to set the ratings (i.e., 1, 2, 1+2=3, 2+3=5, 3+5=8).

The following experiments (in LA-12638) are Project-dependent-only (Proj-do): 104, 106, 201, 202, 204, 305, 401, and 402. The priorities for these experiments are driven by an "engine" different from that driving the remaining experiments. All other experiments are Project-independent (Proj-ind). Proj-ind experiments, however, include two subclasses: Process-dependent (Proc-dep) — 203, 302, 502d, 502e, 502f; and Machine-dependent (Mac-dep) — 105, 206, 207, 502c, and 608. These two subclasses should not be used as discriminators unless specific Process or Machine requirements so warrant.

Experiment 305 should be changed from Pu (300-Series) to HEU (100-Series).
Experiment 201 should be changed from Leu (200-Series) to HEU (100-Series).

Exemplary categorization by Burt Rothleder:

1Exp = ill-defined subcriticality margin: rating = 8;
104, 105, 106, 201, 202, 204, 207, 301, 401, 402, 505, 601, 605a, 609, 701, 702.
2Exp = uncertain protection by well-defined subcriticality margin: rating = 5;
101, 102, 103, 203, 205, 302, 303, 502a, 502d, 502e, 502f, 502g, 502h, 502i, 503, 504, 506, 602, 607.
3Exp = discrepant validation of subcriticality margin: rating = 3;
101, 102, 502a, 605b, 606, 707.
4Exp = criticality safety enhancement through economic gain: rating = 2;
203, 303, 501, 502, 504, 702.
5Exp = enhancement of criticality safety knowledge base: rating = 1;
103, 105, 202, 203, 204, 205, 207, 208, 301, 501, 502, 502a, 502b, 502c, 502d, 502e, 502f, 502g, 502h, 502i, 503, 505, 506, 601, 602, 603, 604, 605, 605a, 605b, 606, 607, 608, 609, 701, 702, 703, 704, 705, 706.

6Exp = economic gain, independently: rating = 0;
502b, 502c.

Undecided (U) or Independent of the rating system (I): rating = 0;
304(I), 305(U), 306(I), 403(U), 507(I), 508(I).

ATTACHMENT 4
CHARTER
Experiment Needs Identification Workgroup
Nuclear Criticality Technology and Safety Project

I. Purpose

The purpose of the Experiment Needs Identification Workgroup is to:

- Identify new criticality experiments and experimental programs needed to support U.S. nuclear facilities.
- Serve as the national focal point for experiment and experimental programs requests.
- Publish a list of the experiment and programmatic needs identified.

II. Scope

The workgroup will identify and prioritize criticality experiments and experimental programs needed to ensure:

- The safe operations of new activities and revisions to existing activities involving fissionable materials in U.S. facilities.
- Criticality safety training.
- Criticality safety with respect to standards and regulations.
- Resolution of criticality physics problems.
- Advancement of criticality safety technology.

III. Membership

Membership will be from personnel or organizations with a vested interest in nuclear criticality safety.

IV. Responsibilities

- The Chair coordinates Workgroup activities.
- The Vice Chair serves in the absence of the Chair.
- The Secretary prepares and distributes meeting minutes.
- The Workgroup reports to DOE through the NCTSP.
- Members attend Workgroup meetings, contribute to the Workgroup report, identify experiment and experimental program needs, prepare programmatic and experiment justification statements, will participate on a voluntary basis, elect a Chair, Vice-Chair, and Secretary.

V. Report

A report listing the identified and prioritized experiments and experimental programs will be sponsored and published through funding from the Nuclear Criticality Technology and Safety Project.

VI. Meetings

The Workgroup will meet at least annually.

This draft Charter for the Experiment Needs Identification Workgroup was reviewed and affirmed at the workgroup meeting on May 10, 1994.

D. A. Rutherford, Chair

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